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(54) **UNIT FOR DETERMINING THE TYPE OF A DOMINATING LIGHT SOURCE BY MEANS OF TWO PHOTODIODES**

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G01J 3/427	(2006.01)
G01J 3/02	(2006.01)

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CPC ***G01J 1/4228*** (2013.01); ***G01J 3/0264*** (2013.01); ***G01J 3/36*** (2013.01); ***G01J 3/427*** (2013.01)

(58) **Field of Classification Search**

CPC G01J 1/4228; G01J 3/0264; G01J 3/36; G01J 3/427

See application file for complete search history.

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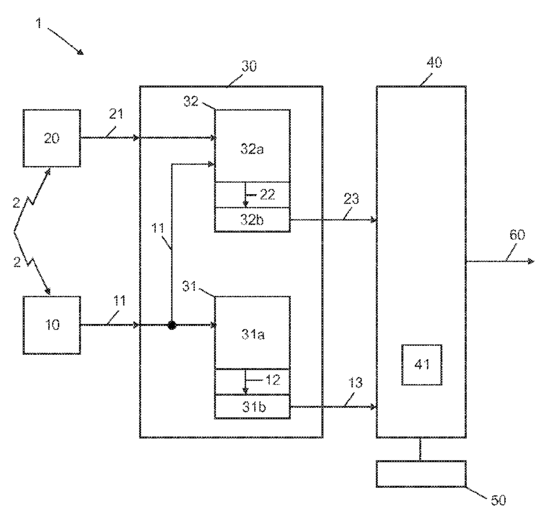
(57) **ABSTRACT**

The invention relates to a unit (**1**) for determining the dominant light source type in electromagnetic radiation (**2**) incident on the unit (**1**) and generated from a plurality of light sources of different types. The unit comprises at least one first photodiode (**10**) designed to detect electromagnetic radiation in the visible spectral range and to generate a first output signal (**11**). The unit comprises at least one second photodiode (**20**) designed to detect electromagnetic radiation in the infrared spectral range and to generate a second output signal (**21**). The unit comprises at least one calculation unit (**30**) designed to derive a quotient result (**23**) and a frequency result (**13**) from the first (**11**) and second (**21**) output signals. The frequency result (**13**) provides information about the presence or absence of signal components in a predetermined frequency range contained in the electromagnetic radiation. The unit comprises at least one evaluation unit (**40**) designed to derive the dominant light source type from the quotient result (**23**) and the frequency result (**13**).

20 Claims, 6 Drawing Sheets



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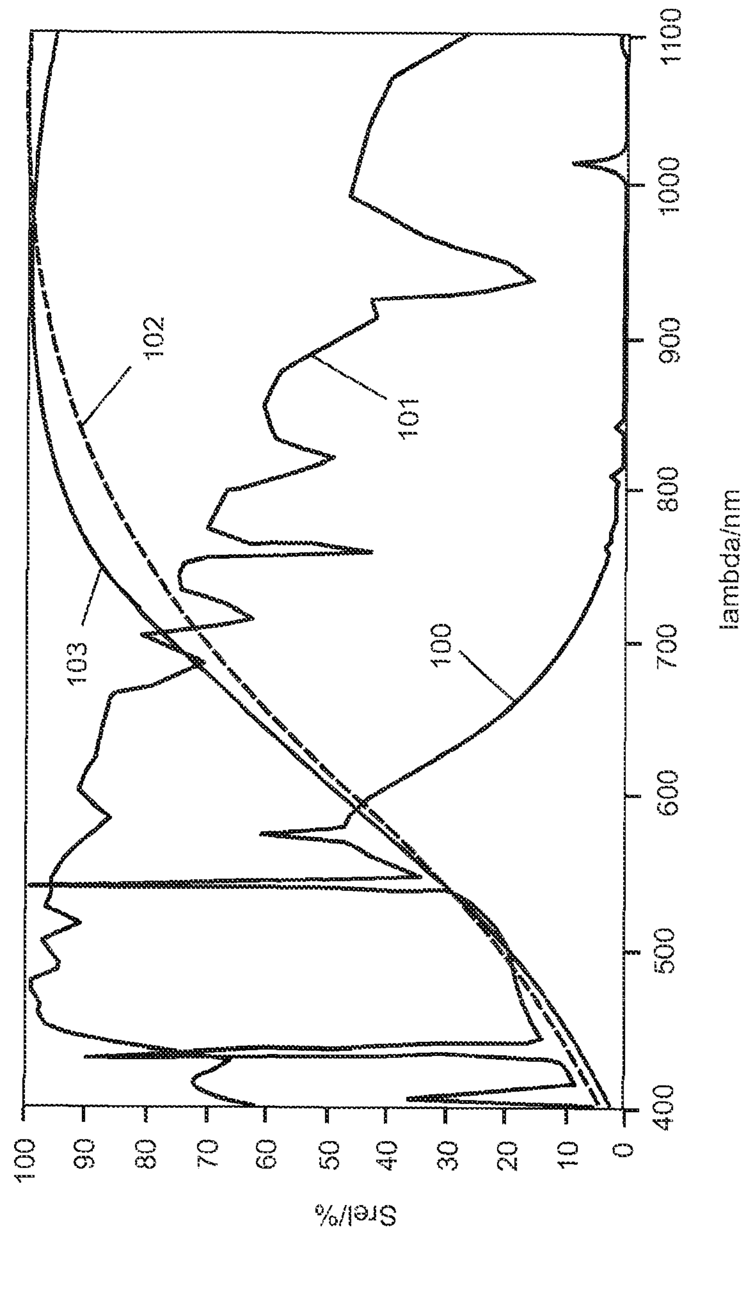
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lambda/nm
100
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102
103

FIG 1

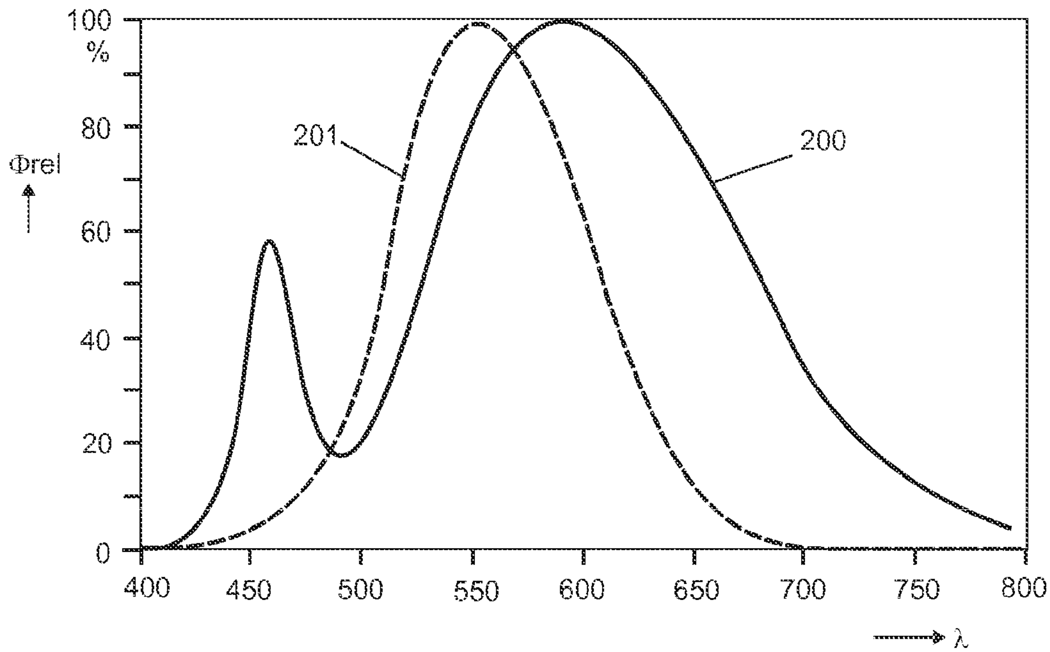
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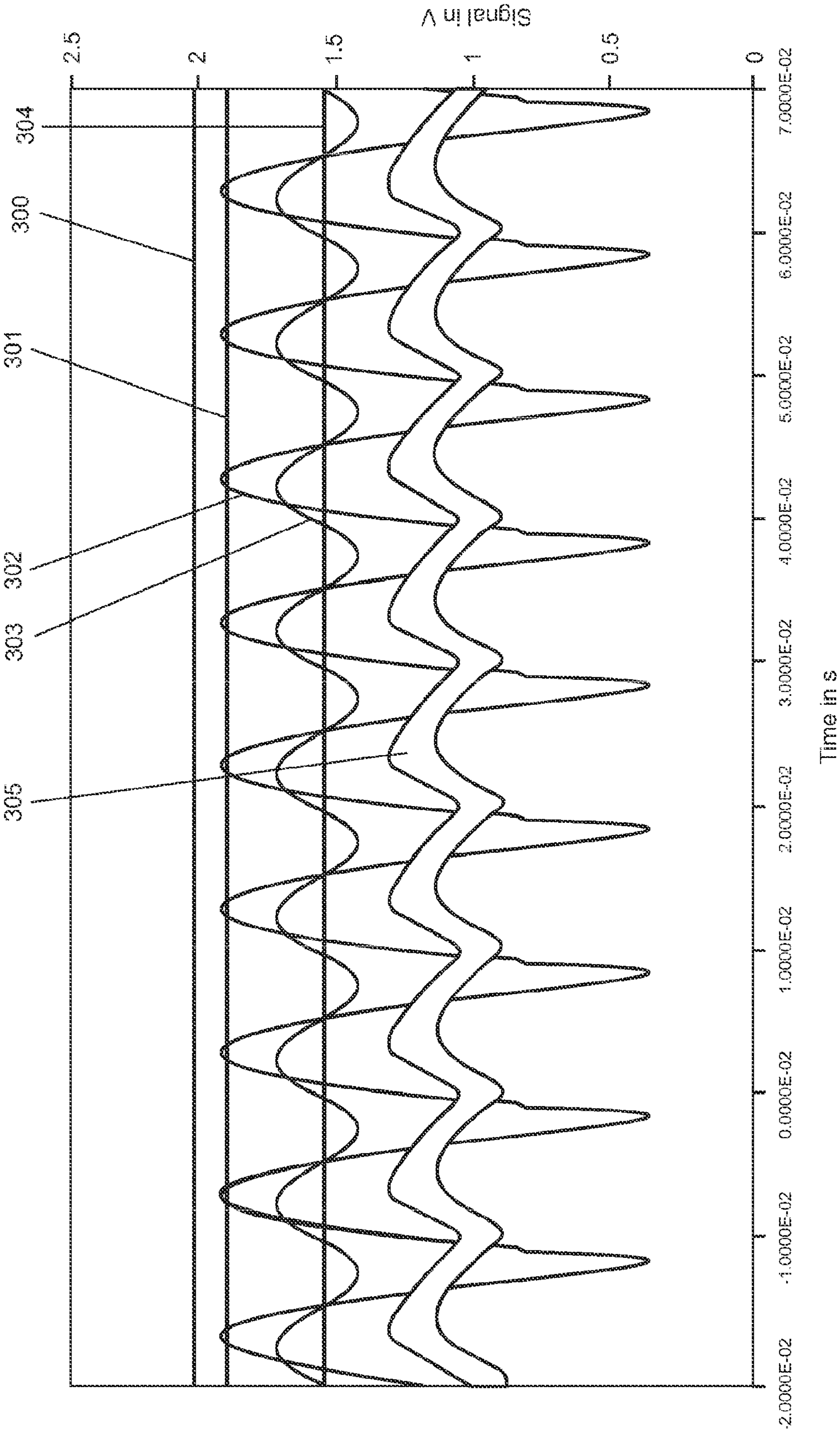
FIG 2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303
304
305
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2
1.5
1
0.5
0
Time in s
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-1.000E-02
0.000E-02
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FIG 3

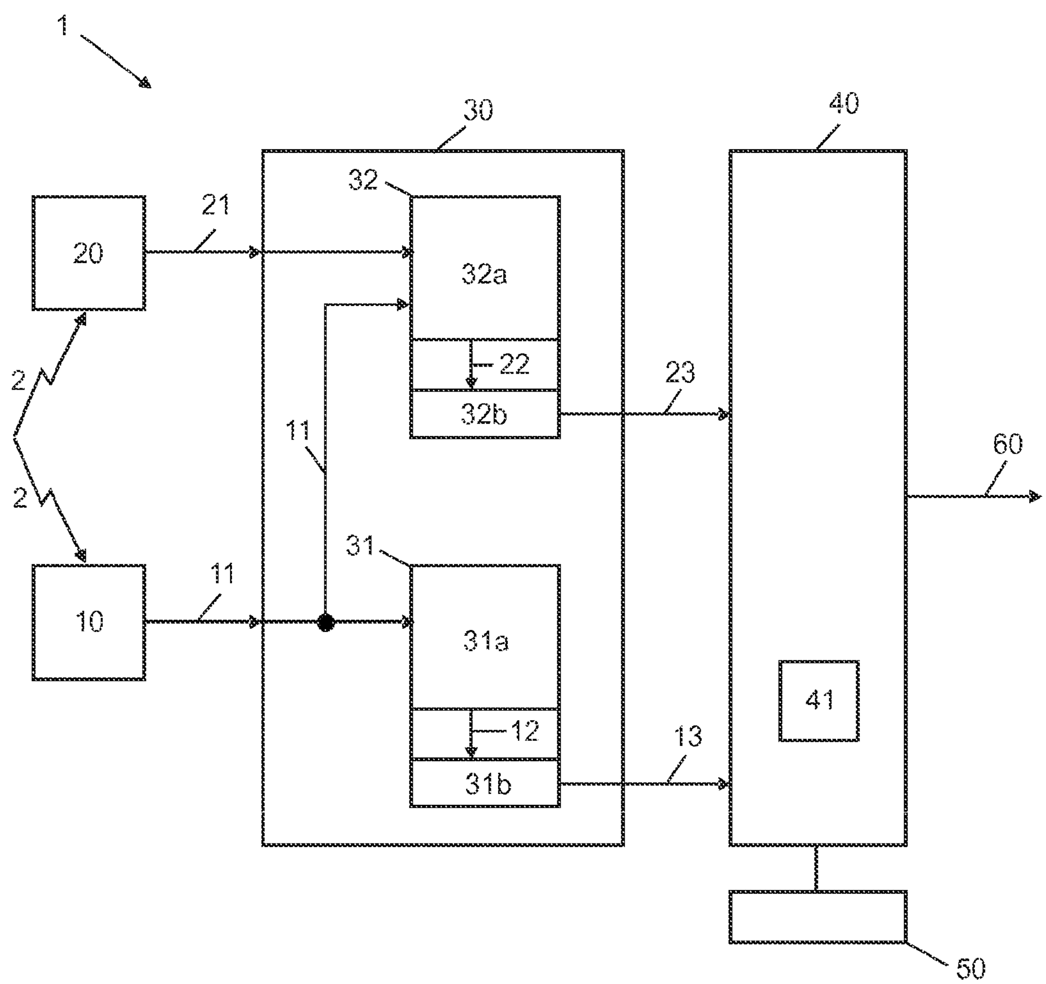

FIG 4

Light source	Constant component of first output signal (ALS)	Constant component of second output signal (IR)	Quotient result (IR/ALS)	Frequency result
Sunlight	high	low	low	0 Hz
Incandescent lamp	low	high	high	50/60 Hz
Torch	low	high	high	0 Hz
Fluorescent lamp	high	low	very low	50/60 Hz
White LED, pulsed	high	low	very low	~ kHz, e.g. 300 kHz
White LED, DC	high	low	very low	0 Hz

FIG 5

Quotient result (23) / Frequency result (13)	high	low	very low
~ kHz e.g. 300 kHz			white LED, pulsed
50/60 Hz	incandescent lamp		fluorescent lamp
0 Hz	torch	sunlight	white LED, DC

FIG 6

UNIT FOR DETERMINING THE TYPE OF A DOMINATING LIGHT SOURCE BY MEANS OF TWO PHOTODIODES

The present invention relates to a sensor for determining the dominant light source type from a plurality of light sources of different types. A measurement method is also provided.

Sensors, in particular colour sensors, which perform a complete spectral analysis are known from the prior art.

A problem associated with these sensors is that they are complex and thus expensive to produce.

This problem is solved by a sensor and a measurement method for producing a sensor according to independent claims **1** and **15** respectively.

Further developments and advantageous configurations of the sensor are indicated in the dependent claims.

EXEMPLARY EMBODIMENTS

Various embodiments comprise a unit for determining the dominant light source type in electromagnetic radiation incident on the unit. The electromagnetic radiation is generated from a plurality of light sources of different types. The unit comprises at least one first photodetector designed to detect electromagnetic radiation in the visible spectral range and to generate a first output signal. The unit comprises at least one second photodetector designed to detect electromagnetic radiation in the infrared spectral range and to generate a second output signal. The unit comprises at least one calculation unit designed to derive a quotient result and a frequency result from the first and second output signals. The frequency result provides information about the presence or absence of signal components in a predetermined frequency range contained in the electromagnetic radiation. The unit comprises an evaluation unit designed to derive the dominant light source type from the quotient result and the frequency result.

Knowledge of the dominant light source type is helpful for reconstruction of the light spectrum and for optimum exposure in photography, in order correctly to reproduce the colour appearance. It allows IR light filtering to be dispensed with in a camera, for example. The colour representation of displays and projectors is corrected as a function of the dominant light source.

Both photodiodes are based on silicon diodes.

The first photodiode comprises a photopic filter, which means that the photodiode is adapted to the spectral sensitivity of the human eye. Such a photodiode is also known as an ambient light diode. This photodiode has its maximum sensitivity at a wavelength of approx. 550 nm and measures between approx. 400 nm and 700 nm. The sensitivity of the first photodiode is adjustable by the number and type of dielectric layers.

The second photodiode comprises an infrared filter. The photodiode has maximum sensitivity at a wavelength of approx. 860 nm and measures between approx. 800 nm and 900 nm. The sensitivity of the infrared sensor is adjusted either by the number and type of dielectric layers or by the use of a daylight filter.

In one preferred embodiment, the first and second photodiodes, the calculation unit and the evaluation unit are embodied by a single integrated circuit. This has the advantage that the sensor can be made as compact as possible.

In one preferred embodiment, the calculation unit comprises a first subunit, which is designed to derive the frequency result in such a way that it provides information about

the presence or absence of components of the first output signal in a predetermined frequency range.

In one preferred embodiment, the first subunit comprises a first determination unit, which comprises a predefined electrical filter. The electrical filter is designed to make separable from one another the constant components of the first output signal by a low-pass filter, the frequency components of the first output signal at 50 Hz and/or 60 Hz by a bandpass filter and the frequency components of the first output signal in the kHz range by a high-pass filter. It is particularly advantageous to use an electrical filter, since this is simple and inexpensive to produce.

In an alternative preferred embodiment, the first subunit comprises a first determination unit, which is designed to integrate the first output signal.

In one preferred embodiment, the first determination unit is designed to carry out a plurality of integrations with different time constants. On the basis of the dependency of signal level on integration time, it is possible to identify the frequency with which the signal was modulated. The integrations may proceed simultaneously or in series.

In one preferred embodiment, the first determination unit is designed to perform a first integration with a first time constant in such a way that the frequency variable includes information about whether the first output signal comprises a spectral component of around 0 Hz.

In one preferred embodiment, the first determination unit is designed to perform a second integration with a second time constant in such a way that the frequency variable includes information about whether the first output signal comprises a spectral component at 50 or 60 Hz.

In one preferred embodiment, the first determination unit is designed to perform a third integration with a third time constant in such a way that the frequency variable includes information about whether the first output signal comprises a spectral component in the kHz range, in particular of around approximately 300 Hz.

In one preferred embodiment, the first subunit comprises a first comparison unit. The first comparison unit is designed to compare the frequency variable with at least one threshold value and to derive a frequency result therefrom.

In one preferred embodiment, the calculation unit comprises a second subunit with a second determination unit, which is designed to derive the quotient variable from a constant component of the first output signal and a constant component of the second output signal.

In one preferred embodiment, the second subunit comprises a second comparison unit, which is designed to compare the quotient variable with at least one threshold value and to derive a quotient result therefrom.

In one preferred embodiment, the evaluation unit is designed to read out an end value from a memory unit for every possible value of the frequency result and every possible value of the quotient result. The end value indicates the dominant light source type, which is derived from the value of the frequency result and of the quotient result.

In one preferred embodiment, the evaluation unit comprises a two-dimensional decision matrix, which contains assignments of frequency results and quotient results to the different light source types.

A measurement method is indicated for determining the dominant light source type in electromagnetic radiation incident on the unit and generated by a plurality of light sources. Electromagnetic radiation in the visible spectral range is detected and a first output signal is generated. Electromagnetic radiation in the infrared spectral range is detected and a second output signal is generated. Then a quotient result and a frequency result are determined from the first and second output signals, the frequency result providing information about the presence or absence of signal components in a predetermined frequency range contained in the electromagnetic radiation. Then the dominant light source type is derived from the quotient result and the frequency result.

BRIEF DESCRIPTION OF THE DRAWINGS

Various exemplary embodiments of the solution according to the invention are explained in greater detail below with reference to the drawings.

FIG. **1** shows the spectra of various light sources;

FIG. **2** shows a comparison of the spectrum of a white LED with the spectral sensitivity of the human eye;

FIG. **3** shows the frequencies of various light sources;

FIG. **4** shows a unit according to the invention;

FIG. **5** shows a first matrix;

FIG. **6** shows a second matrix derived from the first matrix.

EXEMPLARY EMBODIMENTS OF THE OPTOELECTRONIC COMPONENT

Identical, similar or identically acting elements are provided with the same reference numerals in the figures. The figures and the size ratios of the elements illustrated in the figures relative to one another are not to be regarded as being to scale. Rather, individual elements may be illustrated on an exaggeratedly large scale for greater ease of depiction and better comprehension.

FIG. **1** shows the spectra of various light sources. The spectrum of a fluorescent lamp **100** has a high intensity in the visible spectral range, i.e. between wavelengths of 390 nm and 780 nm. In the infrared spectral range, i.e. for wavelengths greater than 780 nm, the spectrum of a fluorescent lamp **100** has almost vanishingly small intensities. The spectrum of sunlight **101** has a high intensity in the visible spectral range and a lower intensity in the infrared spectral range. The spectrum of a thermal radiator **102** at a temperature of 2856 kelvin increases continuously to wavelengths of approx. 1000 nm. The spectrum of an incandescent lamp **103** extends substantially parallel to the spectrum of the thermal radiator **102**.

FIG. **2** shows a comparison of the spectrum of a warm white emitting LED **200** with the curve **201** of the spectral sensitivity of the human eye. The primary maximum of the spectrum of the warm white emitting LED **200** is at a wavelength of approx. 590 nm; a secondary maximum is in the blue spectral range at a wavelength of 460 nm.

FIG. **3** shows the frequencies of various light sources. The light from a torch **300**, a direct current-operated LED **301** and an optical bench **304** is unmodulated, so the frequency is 0 Hz. The light from a fluorescent lamp **302**, an incandescent lamp **303** and an energy-saving lamp **305** is modulated in each case with a frequency of 50 Hz.

FIG. **4** shows the unit **1** for determining the dominant light source type in electromagnetic radiation **2** incident on the unit **1** and generated from a plurality of light sources of different types. The unit comprises a first photodiode **10** designed to detect electromagnetic radiation in the visible spectral range and to generate a first output signal **11**. The unit **1** additionally comprises a second photodiode **20** designed to detect electromagnetic radiation in the infrared spectral range and to generate a second output signal **21**. The unit comprises a calculation unit **30** designed to derive a quotient result **23** and a frequency result **13** from the first **11** and second **21** output signals. The frequency result **13** supplies information about the presence or absence of signal components in a predetermined frequency range contained in the electromagnetic radiation. The unit **1** comprises an evaluation unit **40** designed to derive the dominant light source type from the quotient result **23** and the frequency result **13**.

The first and second photodiodes, **10** and **20** respectively, the calculation unit **30** and the evaluation unit **40** are embodied by a single integrated circuit. The calculation unit **30** comprises a first subunit **31** designed to derive the frequency result **13** in such a way that it provides information about the presence or absence of components of the first output signal **11** in a predetermined frequency range. The first subunit **31** comprises a first determination unit **31***a*, which comprises a predefined electrical filter. The electrical filter is designed to make separable from one another the constant components of the first output signal **11** by a low-pass filter, the frequency components of the first output signal **11** at 50 Hz or 60 Hz by a bandpass filter and the frequency components of the first output signal **11** in the kHz range by a high-pass filter. Alternatively, the first subunit **31** comprises a first determination unit **31***a* designed to integrate the first output signal **11**. The first determination unit **31***a* is designed to perform a plurality of integrations with different time constants. A first integration with a first time constant should be performed in such a way that the frequency variable **12** comprises information about whether the first output signal **11** has a spectral component of around 0 Hz. A second integration with a second time constant should be performed in such a way that the frequency variable **12** comprises information about whether the first output signal **11** has a spectral component at 50 or 60 Hz. A third integration with a third time constant should be performed in such a way that the frequency variable **12** comprises information about whether the first output signal **11** has a spectral component in the kHz range, in particular around approx. 300 kHz.

The first subunit **31** comprises a first comparison unit **31***b* designed to compare the frequency variable **12** with at least one threshold value and to derive a frequency result **13** therefrom.

The calculation unit **30** comprises a second subunit **32** with a second determination unit **32***a*. The determination unit **32***a* is designed to derive the quotient variable **22** from a constant component of the first output signal **11** and a constant component of the second output signal **21**.

The second subunit **32** comprises a second comparison unit **32***b* designed to compare the quotient variable **22** with at least one threshold value and to derive a quotient result **23** therefrom.

The evaluation unit **40** is designed to read out an end value **60** from a memory unit **50** for every possible value of the frequency result **13** and every possible value of the quotient result **23**. The end value **60** indicates the dominant light source type derived from the value of the frequency result **13** and of the quotient result **23**.

The evaluation unit **40** comprises a decision matrix **41**, which contains assignments of frequency results **13** and quotient results **23** to the various types of light source.

FIG. **5** shows for various light sources the values for the constant components of the first output signal **11** in the visible spectral range, for the constant components of the second output signal **21** in the infrared spectral range, for the ratio of constant components of the second output signal **21** to the constant components of the first output signal **11**, here denoted quotient result, and for the frequency result.

FIG. **6** shows the two-dimensional decision matrix **41**, which contains assignments of frequency results **13** and quotient results **23** to the various types of light source. The quotient result **23** is formed from the constant component of the second output signal **21** divided by the constant component of the first output signal **11**. The quotient results **23** may be very low, low or high. The frequency results **13** may be in the kHz range, at 50 Hz or 60 Hz or at 0 Hz. The quotient result **23** for sunlight is low and its frequency result **13** is 0 Hz. The quotient result **23** for an incandescent lamp is high and its frequency result **13** is 50 or 60 Hz. The quotient result **23** for a torch is high and its frequency result **13** is 0 Hz. The quotient result **23** for a fluorescent lamp is very low and its frequency result **13** is 50 or 60 Hz. The quotient result **23** for a pulse-operated white LED is very low and its frequency result **13** is in the kHz range, in particular around 300 kHz. The quotient result **23** for a direct current-operated white LED is very low and its frequency result is 0 Hz.

The unit has been described with reference to a number of exemplary embodiments to illustrate the underlying concept. The exemplary embodiments are not restricted to specific combinations of features. Although some features and configurations have only been described in connection with a particular exemplary embodiment or individual exemplary embodiments, they may in each case be combined with other features from other exemplary embodiments. It is likewise feasible to omit individual described features or particular configurations from or add them to exemplary embodiments, provided the general technical teaching is still embodied

Even if the steps of the measurement method of a sensor are described in a specific sequence, it goes without saying that each of the methods described in this disclosure can be performed in any other meaningful sequence, wherein method steps may also be omitted or added, provided this does not deviate from the basic concept of the described technical teaching.

LIST OF REFERENCE SIGNS

1 Unit/sensor
2 Incident electromagnetic radiation
10 First photodiode
11 First output signal
12 Frequency variable
13 Frequency result
20 Second photodiode
21 Second output signal
22 Quotient variable
23 Quotient result
30 Calculation unit
31 First subunit
31*a* First determination unit
31*b* First comparison unit
32 Second subunit
32*a* Second determination unit
32*b* Second comparison unit
40 Evaluation unit
41 Decision matrix
50 Memory unit
60 End value
100 Spectrum of a fluorescent lamp
101 Spectrum of sunlight
102 Spectrum of a thermal radiator at 2856K
103 Spectrum of an incandescent lamp
200 Spectrum of a white LED
201 Spectral sensitivity of the eye
300 Frequency of a torch
301 Frequency of an OSTAR LED
302 Frequency of a fluorescent tube
303 Frequency of an incandescent lamp
304 Frequency of an optical bench (tungsten lamp at constant power)
305 Frequency of an energy-saving lamp

The invention claimed is:

1. A unit for determining a dominant light source type in electromagnetic radiation incident on the unit and generated from a plurality of light sources of different types, comprising:

at least one first photodiode designed to detect electromagnetic radiation in the visible spectral range and to generate a first output signal;

at least one second photodiode designed to detect electromagnetic radiation in the infrared spectral range and to generate a second output signal;

at least one calculation unit designed to derive a quotient result and a frequency result from the first and second output signals, the frequency result providing information about the presence or absence of signal components in a predetermined frequency range contained in the electromagnetic radiation; and

at least one evaluation unit designed to derive the dominant light source type from the quotient result and the frequency result,

wherein the calculation unit comprises a first determination unit designed to integrate the first output signal, and

wherein the first determination unit is designed to perform a plurality of integrations with different time constants.

2. The unit according to claim **1**, wherein the first and second sensors, the calculation unit and the evaluation unit are embodied by a single integrated circuit.

3. The unit according to claim **1**, wherein the first subunit comprises a first comparison unit designed to compare the frequency variable with at least one threshold value and to derive the frequency result therefrom.

4. The unit according to claim **1**, wherein the calculation unit comprises a second subunit with a second determination unit, which is designed to derive the quotient variable from a constant component of the first output signal and a constant component of the second output signal.

5. The unit according to claim **1**, wherein the evaluation unit is designed to read out from a memory unit, for every possible value of the frequency result and every possible value of the quotient result, an end value indicating the dominant light source type.

6. The unit according to claim **1**, wherein the evaluation unit comprises a two-dimensional decision matrix, which contains assignments of frequency results and quotient results to the different light source types.

7. The unit according to claim **1**, wherein the first determination unit is designed to perform three integrations with three different time constants,

wherein a first integration with a first time constant is performed in such a way for obtaining information about whether the first output signal has a spectral component of around 0 Hz,

wherein a second integration with a second time constant is performed in such a way for obtaining information about whether the first output signal has a spectral component at 50 or 60 Hz, and

wherein a third integration with a third time constant is performed in such a way for obtaining information about whether the first output signal has a spectral component in the kHz range.

8. The unit according to claim **4**, wherein the second subunit comprises a second comparison unit designed to compare the quotient variable with at least one threshold value and to derive a quotient result therefrom.

9. A unit for determining a dominant light source type in electromagnetic radiation incident on the unit and generated from a plurality of light sources of different types, comprising:

at least one first photodiode designed to detect electromagnetic radiation in the visible spectral range and to generate a first output signal, wherein the first photodiode is formed as an ambient light diode, such that the first photodiode is adapted to the spectral sensitivity of the human eye;

at least one second photodiode designed to detect electromagnetic radiation in the infrared spectral range and to generate a second output signal;

at least one calculation unit designed to derive a quotient result and a frequency result from the first and second output signals, the frequency result providing information about the presence or absence of signal components in a predetermined frequency range contained in the electromagnetic radiation; and

at least one evaluation unit designed to derive the dominant light source type from the quotient result and the frequency result,

wherein the calculation unit comprises a first subunit having a first determination unit,

wherein the first determination unit is designed either to:

integrate the first output signal, or

comprises a predefined electrical filter designed to make separable from one another the constant components of the first output signal by a low-pass filter, the frequency components of the first output signal at 50 Hz or 60 Hz by a bandpass filter and the frequency components of the first output signal in the kHz range by a high-pass filter,

wherein the first subunit further comprises a first comparison unit designed to compare a frequency variable with at least one threshold value and to derive the frequency result therefrom,

wherein the calculation unit further comprises a second subunit having a second determination unit,

wherein the second determination unit is designed to derive a quotient variable from a constant component of the first output signal and a constant component of the second output signal, and

wherein the second subunit comprises a second comparison unit designed to compare the quotient variable with at least one threshold value and to derive the quotient result therefrom.

10. The unit according to claim **9**, wherein the first photodiode has its maximum sensitivity at a wavelength of about 550 nm and measures electromagnetic radiation having a wavelength between 400 nm and 700 nm.

11. The unit according to claim **9**, wherein the calculation unit comprises a first subunit designed to derive the frequency result in such a way that it provides information about the presence or absence of components of the first output signal in a predetermined frequency range.

12. The unit according to claim **11**, wherein the first subunit comprises a first determination unit, which comprises a predefined electrical filter designed to make separable from one another the constant components of the first output signal by a low-pass filter, the frequency components of the first output signal at 50 Hz or 60 Hz by a bandpass filter and the frequency components of the first output signal in the kHz range by a high-pass filter.

13. The unit according to claim **11**, wherein the first subunit comprises a first determination unit designed to integrate the first output signal.

14. The unit according to claim **11**, wherein the first subunit comprises a first determination unit which is designed to identify a modulation frequency of the first output signal by performing a plurality of integrations with different time constants.

15. The unit according to claim **13**, wherein the first determination unit is designed to perform a plurality of integrations with different time constants.

16. The unit according to claim **15**, wherein the first determination unit is designed to perform a first integration with a first time constant in such a way that the frequency variable comprises information about whether the first output signal comprises a spectral component of around 0 Hz.

17. The unit according to claim **15**, wherein the first determination unit is designed to perform a second integration with a second time constant in such a way that the frequency variable comprises information about whether the first output signal comprises a spectral component at 50 or 60 Hz.

18. The unit according to claim **15**, wherein the first determination unit is designed to perform a third integration with a third time constant in such a way that the frequency variable comprises information about whether the first output signal comprises a spectral component in the kHz range.

19. A measurement method for determining, by a unit, the dominant light source type in electromagnetic radiation incident on the unit and generated from a plurality of light sources, the method comprising:

detecting electromagnetic radiation in the visible spectral range and generating a first output signal;

detecting electromagnetic radiation in the infrared spectral range and generating a second output signal;

deriving, by a calculation unit, a quotient result and a frequency result from the first and second output signals, the frequency result containing information about the presence or absence of signal components in a predetermined frequency range contained in the electromagnetic radiation; and

deriving the dominant light source type from the quotient result and from the frequency result,

wherein the calculation unit comprises a first determination unit designed to integrate the first output signal, and

wherein the first determination unit is designed to perform a plurality of integrations with different time constants.

20. The measurement method according to claim **19**, wherein the first determination unit is designed to perform three integrations with three different time constants,

wherein a first integration with a first time constant is performed in such a way for obtaining information about whether the first output signal has a spectral component of around 0 Hz,

wherein a second integration with a second time constant is performed in such a way for obtaining information about whether the first output signal has a spectral component at 50 or 60 Hz, and

wherein a third integration with a third time constant is performed in such a way for obtaining information about whether the first output signal has a spectral component in the kHz range.

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